

## Risk Factors for Desaturation After Tonsillectomy: Analysis of 4092 Consecutive Pediatric Cases

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**Objectives/Hypothesis:** To identify clinical risk factors for oxygen desaturation in the first 24 hours post-tonsillectomy, thus permitting the identification of those patients who warrant inpatient monitoring.

**Study Design:** A retrospective analysis of 4092 consecutive patients undergoing tonsillectomy over a two-year period.

**Methods:** Detailed clinical data were recorded for all patients who desaturated in the postoperative period (n = 294) and randomly selected controls (n = 368). Univariate and Multivariate analysis was performed in order to identify independent risk factors for desaturation.

**Results:** There were 294/4092 patients (7.2%) who experienced desaturations (defined as sustained saturations <90%) in the first 24 hours postoperatively (mean nadir, 78.7%). Multivariate analysis identified seven independent clinical risk factors for desaturation in the initial 24 hours post-tonsillectomy: trisomy 21, weight, coexistent cardiac disease, a coexistent syndromic diagnosis, a clinical diagnosis of obstructive sleep apnea (OSA), a coexistent neurologic diagnosis, and a prior diagnosis of pulmonary disease. A policy that admits all patients exhibiting any one of these risk factors except OSA would have identified 92% of the patients who subsequently desaturated. However, such a policy would also have required admission of 60% of the patients in our control group.

**Conclusions:** These findings are generally consistent with the Clinical Practice Guidelines recently published by the American Academy of Otolaryngology. In a tertiary care center, it may not be possible to identify an algorithm that admits all children at risk of desaturation while permitting the discharge of a high percentage of patients.

**Key Words:** Tonsillectomy, adenotonsillectomy, sleep, sleep-disordered breathing, obstructive sleep apnea, respiratory complications, oxygen desaturation, polysomnography, monitoring.

**Level of Evidence:** 3b.

*Laryngoscope*, 123:2554–2559, 2013

### INTRODUCTION

Although tonsillectomy is currently performed less frequently than in the past, it remains one of the most common surgical procedures in the Western world.<sup>1</sup> Although death post-tonsillectomy is rare in the modern era, with estimated mortality rates of 1 per 16,000 to 35,000 tonsillectomies,<sup>2,3</sup> morbidity remains common. The most common significant morbidities are bleeding and respiratory complications.

The increasing recognition of childhood obstructive sleep apnea (OSA) and the importance of the benefits of treatment have led to more adenotonsillectomies being performed for sleep-related conditions.<sup>4</sup> Adenotonsillectomy is

curative for pediatric OSA in the majority of patients.<sup>5,6</sup> Potential benefits include improved sleep, growth, school performance, and cardiac function.<sup>7,8</sup> In consequence of the increasing frequency of adenotonsillectomy for OSA, adenotonsillectomy is now more often performed in younger children and in children with significant medical comorbidities. Respiratory complications occur in 5% to 25% of patients undergoing tonsillectomy for OSA<sup>9–14</sup> compared to roughly 1% in patients without OSA.<sup>15–17</sup> Respiratory complications are more likely to occur in certain clinical scenarios: urgent tonsillectomy for severe OSA,<sup>18</sup> children with OSA who are younger than 3 years old,<sup>19</sup> and in those with medical comorbidities such as asthma, bronchopulmonary dysplasia, and neuromuscular and craniofacial abnormalities.<sup>9–11,20,21</sup> In an attempt to predict the likelihood of postoperative respiratory complications, polysomnography (PSG) is often performed. However, the ability of PSG to predict postoperative respiratory complications has yet to be clearly established.<sup>22</sup> The American Academy of Otolaryngology's Clinical Practice Guideline recommends PSG in children suffering from symptoms of OSA prior to adenotonsillectomy if they exhibit certain medical comorbidities: obesity, trisomy 21, craniofacial abnormalities, neuromuscular disorders, sickle cell disease, or certain inherited metabolic conditions.<sup>22</sup> This guideline document also suggests that overnight admission be considered for children with OSA if they are younger than 3 years of age or have severe OSA on PSG.

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Editor's Note: This Manuscript was accepted for publication November 29, 2012.

Presented at the Triological Society 115th Annual Meeting at COSM, San Diego, California, U.S.A., April 20, 2012.

The authors have no funding, financial relationships, or conflicts of interest to disclose.

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DOI: 10.1002/lary.23956

These guidelines are limited by the fact that not all patients with symptoms of sleep-disordered breathing undergo preoperative PSG, and that patients may undergo adenotonsillectomy for recurrent infection and have unrecognized sleep-disordered breathing. We therefore designed this study to assess the prevalence of and risk factors for desaturations in all patients undergoing tonsillectomy, regardless of indication.

We hypothesized that the risk factors for desaturation are the same or similar to the risk factors for major respiratory complications. Because many more children suffer desaturations than have major respiratory complications, it was possible for us to conduct a much larger and more statistically valid study of the risk factors for desaturations than of those for major respiratory complications.

## MATERIALS AND METHODS

### Study Design

This study received prior approval from the institutional review board at Children's Hospital Boston. A retrospective review was performed of the medical records of 4,092 consecutive patients who underwent tonsillectomy, with or without adenoidectomy, performed at Children's Hospital Boston and two satellite centers. The otolaryngology department maintains a prospective database of all surgical cases that has been verified on a number of occasions to be complete. This represented a consecutive series of patients over an approximate 2-year period between January 5, 2009 and May 9, 2011. There were no exclusion criteria.

### Case and Control Definitions

A case was defined as any patient who had a recorded sustained oxygen saturation of <90% in the medical postoperative notes, nursing postoperative notes, or in the vital signs log in the first 24 hours postoperatively. Any free text entered in the electronic medical records at the time of desaturation was checked to ensure that the recorded desaturation was not secondary to malfunction or malposition of the oximeter. The control group was randomly selected from all other patients using the random number generator function of Microsoft Excel (Microsoft Corp., Redmond, WA).

The entire electronic medical records of all cases and controls were reviewed for clinical information (symptomatology, clinical findings, body mass index [BMI], past medical history), results of investigation (sleep studies), demographic information (age, date of surgery, admission floor and location), and details of the desaturation (oxygen saturation nadir). These data were entered into a custom-built database (Microsoft Access 2003; Microsoft Corp.). Electronic medical record review was performed by a single author to ensure consistency (C.G.). A random selection of 10% of both cases and controls were reviewed by two further authors to ensure validity (A.K., S.K.). In two patients there was initial disagreement about the presence of desaturations, which were only recorded in the intensive care unit nursing admission note and not the vital signs section. Three other minor discrepancies were identified during this process, regarding the recording of sleep study data and operative data. These were reviewed and resolved by the senior author (D.R.).

To facilitate comparisons, medical comorbid diagnoses were assigned collective groupings, specifically: neurological, cardiac, pulmonary, airway, trisomy 21, or other syndromes.

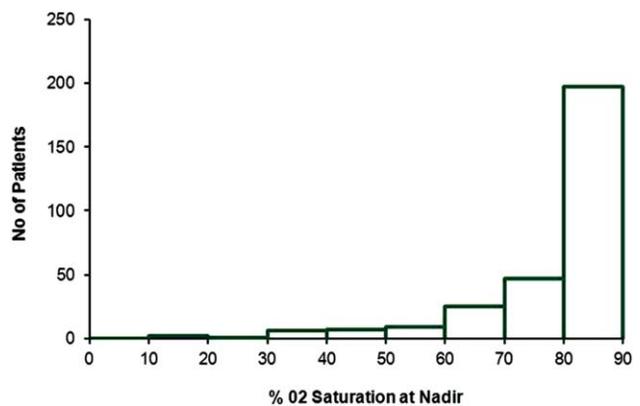


Fig. 1. Histogram of oxygen saturation nadir among those patients who desaturated. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://wileyonlinelibrary.com).]

The pulmonary diagnosis category encompassed lower airway pathology (i.e., asthma, bronchopulmonary dysplasia, history of recurrent pneumonia), whereas the airway category denoted nonadenotonsillar upper airway pathology (i.e., laryngomalacia or subglottic stenosis). The broad other syndromes category included patients with significant syndromic disease not pertaining to the other categories, including achondroplasia, inherited metabolic conditions, and craniofacial abnormalities.

The procedure performed was recorded as either tonsillectomy, tonsillectomy with adenoidectomy, tonsillectomy, or tonsillectomy with adenoidectomy. Technique was at the discretion of the attending surgeon. Tonsillectomy was performed utilizing a monopolar electrocautery technique or coblation. Tonsillectomy was performed using a specifically designed microdebrider blade (Medtronic, Minneapolis, MN). Adenoidectomy was most often performed by either suction monopolar electrocautery or using an adenoid microdebrider blade (Medtronic).

### Statistical Analysis

Categorical variables were summarized using proportions. Continuous data were presented as a mean  $\pm$  standard deviation. For continuous variables, bivariate comparisons were made with the use of the Student *t* test. For categorical variables, the unadjusted odds ratio and 95% confidence interval were determined, with groups compared using the  $\chi^2$  test or Fisher exact test. Basic descriptive analyses were performed with PROC FREQ SAS/STAT software version 9.2 (2008) (SAS Institute Inc., Cary, NC). Logistic regression analyses were conducted with PROC LOGISTIC to determine the significant predictors of desaturation, the outcome of interest. Univariate analyses were conducted to determine the variables that were significant predictors of desaturation. Variables that were significant in the univariate analyses were evaluated for inclusion in a multivariate model. There were no interactions among variables. A *P* value of <.05 was considered statistically significant.

## RESULTS

### Patient Groups

In the 4,092 patients who underwent surgery in the study period, 294 (7.2%) had oxygen saturations <90% recorded during their hospital stay. Of the patients who desaturated postoperatively, the mean saturation nadir was 78.7%, with a minimum documented saturation of

TABLE I.  
Demographic and Basic Clinical Characteristics of Patients in the Desaturation Group and the Nondesaturation (Control) Group.

	Desaturations, n = 294	No Desaturations, n = 368	Odds Ratio (95% CI)	P
Age, mean ( $\pm$ SD), mo	60.0 ( $\pm$ 48.6)	82.6 ( $\pm$ 50.2)	NA	<.0001
Age				
<2 years	33 (11.2%)	7 (1.9%)	6.5 (2.8–15.0)	<.0001
<3 years	110 (37.4%)	50 (13.6%)	3.8 (2.60–5.6)	<.0001
Weight, mean ( $\pm$ SD)	23.6 ( $\pm$ 22.7)	28.0 ( $\pm$ 18.4)	NA	0.0057
BMI, mean ( $\pm$ SD)	18.6 ( $\pm$ 6.4)	17.9 ( $\pm$ 4.20)	NA	NS
Weight				
<20 kg	209 (71%)	159 (43.2%)	2.9 (2.1–4.0)	<.0001
<15 kg	130 (44.2%)	74 (20.10%)	3.2 (2.2–4.4)	<.0001
Surgical indication				
OSA	267 (90.8%)	278 (75.5%)	3.20 (2.01–5.08)	<.0001
Tonsillitis	31 (10.54%)	108 (29.35%)	0.28 (0.18–0.44)	<.0001
Dysphagia	13 (4.44%)	17 (4.62%)	0.96 (0.46–2.00)	NS
PFAPA	3 (1.02%)	7 (1.9%)	0.53 (0.14–2.074)	NS
Other	19 (6.36%)	25 (6.79%)	0.95 (0.51–1.76)	NS

Some patients had more than one indication for surgical intervention. OSA was determined primarily on clinical grounds, as the majority of patients did not have a polysomnography.

BMI = body mass index; CI = confidence interval; OSA = obstructive sleep apnea; PFAPA = periodic fever, aphthous stomatitis, pharyngitis, adenitis syndrome; NA = not applicable; NS = not statistically significant.

10%. Figure 1 demonstrates the distribution of the oxygen nadir in all patients who desaturated. The majority of desaturations were mild (nadir between 80% and 90%).

Table I shows the demographics and basic clinical characteristics of the desaturation and control groups. The children who desaturated were on average younger, smaller, heavier for age (greater BMI), and were slightly more likely to have had their tonsillectomy performed for OSA than the controls.

### Medical Comorbidities

At least one medical comorbidity was present in 68.37% of the desaturation group and 35.33% of the non-desaturation group. The distribution of each comorbidity and its odds ratio of each comorbidity are shown in Table II.

### PSG and AHI

In the group of patients who desaturated postoperatively, 102 (34.7%) had had a preoperative PSG versus 51 patients (13.9%) in the control group. Having a preoperative PSG conferred an odds ratio for desaturation of 3.3 (95% confidence interval [CI], 2.3–4.8). The mean ( $\pm$ standard deviation) apnea-hypopnea index (AHI) was significantly higher in those patients who desaturated postoperatively ( $14.2 \pm 19.5$  vs.  $5.9 \pm 9.2$ ). The odds ratio of desaturation was 4.4 (95% CI, 2.0–9.4,  $P < .0001$ ) for an AHI of  $> 3$ , and 4.1 (95% CI, 1.7–9.6,  $P = .0008$ ) for an AHI  $> 10$ . In these 102 patients who desaturated and had had a preoperative PSG, there was no correlation between the AHI and the nadir of their subsequent postoperative desaturation (Pearson correlation  $r = -0.06$ ; 95% CI,  $-0.25$  to  $0.13$ ).

TABLE II.  
Distribution and Results of Univariate Analysis for the Six Categories of Medical Comorbidities (and Any Comorbidity) Encountered in Both Patient Groups in Order of Predictive Value.

	Desaturations, n = 294	No Desaturations, n = 368	Odds Ratio (95% CI)	P
Trisomy 21	28 (9.5%)	4 (1%)	9.6 (3.7–32.6)	<.0001
Cardiac disease	60 (20.4%)	18 (4.9%)	5.0 (2.9–8.9)	<.0001
Neurologic disease	71 (24.2%)	32 (8.7%)	3.3 (2.1–5.3)	<.0001
Other syndromes	98 (33.3%)	48 (13%)	3.3 (2.3–4.9)	<.0001
Pulmonary disease	78 (26.5%)	61 (16.6%)	1.8 (1.2–2.7)	.002
Airway disorder (nonlymphoid)	40 (13.6%)	30 (8.2%)	1.8 (1.1–3.0)	<.025
Any comorbidity	201 (68.4%)	126 (34.2%)	4.1 (3.0–5.8)	<.0001

CI = confidence interval.

TABLE III.  
Results of Multivariate Analysis of Variables Independently Associated With Desaturations in Order of Predictive Value.

	Odds Ratio (95% CI)	P
Trisomy 21	4.4 (1.6–16.0)	.011
OSA (clinical diagnosis)	2.8 (1.7–4.7)	<.001
Other syndrome	2.5 (1.6–3.9)	<.001
Cardiac disease	2.3 (1.2–4.5)	.0104
Neurologic disease	2.1 (1.3–3.4)	.005
Weight <20 kg	1.7 (1.1–2.5)	<.001
Pulmonary disease	1.6 (1.1–2.4)	.026

By definition, all included variables are statistically significant. Age and weight were highly correlated, and thus age was excluded from this analysis. This does not imply that age is not a risk factor for desaturation.

CI = confidence interval; OSA = obstructive sleep apnea.

### Desaturations in Patients Without the Diagnosis of OSA

Twenty-seven patients (9.2%) who desaturated did not have a preoperative clinical diagnosis of OSA. However, only eight of these patients did not suffer from a coexisting medical comorbidity, and of these eight patients only one patient desaturated lower than 83% (to 65%).

### Multivariate Analysis

All variables (demographic and clinical) that were significant in a univariate analyses were evaluated for inclusion in a multivariate model. Seven variables were identified by multivariate analysis to be associated with oxygen desaturation following adenotonsillectomy, with no interaction between the variables (Table III). Age and weight were found to strongly correlate, therefore only weight was brought forward to the multivariate analysis. AHI was excluded, as only a small proportion of our patients had undergone a preoperative PSG.

## DISCUSSION

Although tonsillectomy has become a safe operation, major morbidity and mortalities may still occur. A substantial fraction of post-tonsillectomy deaths have been reported to occur without apparent etiology within 24 to 48 hours postoperatively.<sup>23</sup> It seems plausible that these are apneic deaths, related to a multifactorial insult to the respiratory drive in the immediate postoperative period. If so, it is likely that overnight monitoring would allow prompt intervention for apnea, and thus prevent these fatalities.

However, as an estimated 530,000 pediatric tonsillectomies were performed in the United States in 2006, the societal cost of admitting every patient for monitoring is in the hundreds of millions of dollars.<sup>24</sup> Conversely, a strategy that allowed safe discharge of a large fraction of these patients would avoid needless hospital stays for children and their families, and avoid hundreds of millions of dollars of unnecessary expense.

Currently, there is extraordinary variability in admission practices, both among national peer hospitals<sup>25</sup>

and among different health structures. In some European countries, all tonsillectomy patients are routinely admitted for the first 3 postoperative nights, regardless of indication.<sup>26</sup> In the United States, in contrast, day-case tonsillectomy has come to be considered safe by most health care providers and generally accepted by parents.<sup>27,28</sup>

However, as day-case tonsillectomy has become standard practice in North America, the most common indication for surgery has also been changing. Tonsillectomy for recurrent tonsillitis has become less common, with the introduction of more stringent patient selection criteria,<sup>29,30</sup> and simultaneously there has been increased awareness of pediatric sleep-disordered breathing, which is now the most common indication for pediatric tonsillectomy in the United States.<sup>4,31</sup> Left untreated, pediatric sleep apnea is recognized to have negative pulmonary, cardiac, neurologic, and neurocognitive function, and educational sequelae.<sup>7,8,32–36</sup> The heightened awareness of the negative consequences of pediatric OSA has resulted in tonsillectomy being performed in younger and more medically complex patients; in this group of patients, there is an increased concern for postoperative respiratory complications.<sup>11,18–20</sup> Major respiratory complications may necessitate intubation and other major interventions, which are only immediately available in the hospital setting.<sup>19,20</sup>

The rarity of major respiratory complications and death make risk factors for these events all but impossible to study in a formal manner. To gain insight as to which patients might be at risk for serious events, we made the assumption that the risk factors for postoperative desaturation would be similar to the risk factors for postoperative apneic death. Although this assumption is not provable, we believe it has high face validity and clinical plausibility.

Using univariate and subsequent multivariate analysis, we identified seven independent risk factors for oxygen desaturation in the first 24 hours post adenotonsillectomy: trisomy 21, cardiac disease, OSA (clinical diagnosis), other related syndromes, weight, neurologic disease, and pulmonary disease.

In a univariate model, age <2 years was more predictive of desaturation than age <3 years, and weight <15 kg was slightly more predictive than weight <20 kg, but due to the high correlation of these variables it was necessary to only utilize one in the multivariate analysis. We chose to use weight <20 kg due to its wide clinical utility. It is clear, however, that both younger age and lower weight are risk factors for desaturation.

Because many of our patients' heights were never recorded, we were unable to calculate BMI for the majority of our patients. Among those for whom BMI was available, it was unsurprisingly higher in the group that desaturated. Because of the small number of observations, it was not possible to include BMI in the multivariate analysis. This finding emphasizes the point that postoperative desaturations occur in patients at the extremes of the weight distribution—young and light patients as well as older obese patients.

Likewise, although an AHI of 3 and an AHI of 10 were both predictive of increased risk of postoperative desaturations, we could not include these variables in the multivariate analysis, as only a minority of our patients had PSGs. The significance of AHI is further clouded by the fact that the selection of patients for PSG is highly biased (as demonstrated by the fact that merely having a sleep study was a risk factor for postoperative desaturation).

An AHI of 10 was no more predictive of desaturation than an AHI of 3. If this is a meaningful finding, it means that milder degrees of OSA on sleep study should still be considered a risk factor for postoperative desaturation.

We examined the consequences of a policy that admits all patients exhibiting any one of these risk factors except the clinical diagnosis of OSA. Such a policy would have identified 92% of patients who subsequently desaturated, based on purely clinical factors. However, such a policy would have required admission of 60% of the patients in our control group who did not desaturate. Thus, in a population in which roughly one-third of the patients have one or more medical comorbidity, it may be difficult or impossible to admit all patients at risk for desaturation and simultaneously discharge a high percentage of patients. In a less medically compromised population, however, it may be possible to do so.

A small number of patients (9.2%) who desaturated did not have a preoperative diagnosis of OSA. However, the majority suffered from at least one other medical comorbidity, and of those with a normal medical history the desaturation tended to be mild in nature. One patient with no comorbidities did desaturate to 65%. We would suggest that patients with medical comorbidities are at risk regardless of the indication for their tonsillectomy.

Only 34.5% of patients who desaturated and 13.9% of patients in the control group had undergone preoperative PSG. This is consistent with the finding of a survey performed in 2004 of members of the American Society of Pediatric Otolaryngology, which revealed that the majority relied on a clinical diagnosis of OSA prior to tonsillectomy, with 75% of respondents utilizing PSG in <10% of children who presented with sleep disturbance.<sup>31</sup> In light of the recent clinical practice guidelines and increased pediatric sleep laboratory availability, we expect an increased number of patients will undergo PSG in the future.<sup>22</sup>

### Limitations

This study has several important methodological strengths and limitations. It is a complete consecutive series of over 4,000 patients undergoing tonsillectomy ± adenoidectomy at a tertiary care hospital. Every chart was reviewed for the finding of interest (desaturation), and the controls were selected in a completely random fashion.

A total of 115 patients (31.3%) in our control group were done as day cases. In our institution, all day-case tonsillectomy patients are observed for >4 hours prior to discharge. We made the (unverifiable) assumption that if they did not experience desaturation during this period, then they could be included as controls. Unless an

implausibly high fraction of these patients experienced desaturations after discharge, however, the results of the analysis would not change substantially.

A further limitation was relying on the clinical diagnosis of OSA, which was made by >10 different physicians. It is well known that the clinical diagnosis of OSA is imperfect.<sup>37</sup>

Finally, this study was done at a tertiary care pediatric hospital, and 35% of the control population had at least one comorbidity. In a less medically compromised population, the absolute risk of desaturation would of course be lower.

### CONCLUSION

Oxygen desaturation to <90% occurs in 7% of patients following adenotonsillectomy in a tertiary care center. We identified a number of important risk factors for postoperative desaturation and hypothesize that these may also be risk factors for apneic death following tonsillectomy. Our findings are in general agreement with the American Academy of Otolaryngology–Head and Neck Surgery guideline on tonsillectomy. In a tertiary care population, it may be difficult to discharge a high percentage of patients and still monitor those patients at risk for desaturation and possibly more serious respiratory complications.

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